



This document contains the Appendix B: Indicators Developed by Various Groups, and Appendix C: Resources on Indicators, for the Indicator Development for Estuaries report. EPA-842-B-07-004.

The remainder of the document can be downloaded from:
<http://www.epa.gov/owow/estuaries/indicators/>

Indicator Development for Estuaries

February 2008

APPENDIX B

INDICATORS DEVELOPED BY VARIOUS GROUPS

The following is a list of indicators chosen by various groups for monitoring progress within estuaries or coastal areas around the United States. The list is divided into six categories:

- Fisheries
- Contaminants/water quality
- Contaminants/sediments
- Land use change
- Aquatic habitat
- Other

Fisheries

- Trends, abundance, and diversity (total number of species, total number of individuals, and biomass) in fish, shellfish, and crustaceans
- Toxic tissue concentration and trends of contamination (metals, polycyclic aromatic hydrocarbon [PAHs], polychlorinated biphenyls [PCBs], pesticides, dioxins, furans, and dichlorodiphenyltrichloroethane [DDT]) in lobsters, shellfish, and fish
- Public health risks from toxic contaminants in fish and shellfish tissue
- Fish diseases (observation of fish diseases [fin erosion, tumor, etc.] or individual fish samples)
- Changes in the health, ecology, or other effects on recreational fish
- Weights of fish populations
- Number of fish kills
- Biodiversity of bottom-dwelling species and mid-water species
- Status of shellfish beds (changes in acreage of closed and open shellfish flats)
- Changes in the health, ecology or other effects on landings (catch and effort, catch-per-unit-effort [CPUE])
- Shellfish habitat (acres of shellfish beds classified as suitable for harvesting and for seed stock)
- Shellfish harvest (bushels of oyster harvested annually and dollar value of the harvest)
- Density of harvestable clams flats
- Abundance of shellfish predators
- Weight of shellfish landings
- Disease linked to contaminated shellfish

INDICATORS DEVELOPED BY VARIOUS GROUPS

- Recreational harvest of clams
- False mussel stands
- Oysters (population, restored beds [acres], bed acres restored with disease resistant American oyster stock, disease, bed acreage)
- Recreational harvest of oysters
- Oyster density on public seed grounds over time
- Oyster abundance and health on private leases
- Bacteriological water quality of oyster harvesting waters
- Lobster harvest (pounds of lobster harvested)
- Lobster permits (permits and licenses)
- Anadromous fish runs
- Anadromous fish returns
- Annual number of fish migrating down stream
- Number of stream miles opened through fish passage enhancement projects
- Stream miles opened to migratory fish
- Public use and access
 - fish advisories
 - fish tissue - persistent, bioaccumulative, and toxic contaminant levels
 - percent of streams impaired for fishing
 - shellfish bed closures
- Right whale populations: number of right whales
- Macroinvertebrates (freshwater)
- Biological production and respiration (phytoplankton and zooplankton productivity, abundance, and composition, bacterial production, respiration)
- Macrophyte abundance and composition
- Estimated economic impact of recreational fishing over time
- Value and number of licenses of commercial and recreational fishing
- Change in number of saltwater fishing licenses
- Acres of commercial shellfish areas (total acres of open, restricted, closed, and prohibited commercial shellfish areas)
- Commercial fishing pressure (weight [pounds] of commercial catch)
- Recreational fishing pressure (recreational CPUE for targeted resident fish species)
- Presence absence of disturbance indicator species, non-native fish
- Occurrence of non-native crabs

Contaminants/Water Quality

- Water quality (temperature, salinity, pH, turbidity, dissolved oxygen [DO], chlorophyll-*a*, total dissolved solids, total suspended solids, nutrients, phosphorus, nitrates, metals, organics)
- Light attenuation (secchi disk depths, or some equivalent measure of light attenuation)
- Point source and non-point source nitrogen loading
- Trophic state index of water
- Isohaline locations

- Atrazine concentration in surface waters over time
- Atmospheric deposition
- Number and duration of high-chloride events in source water to the Clotilda drinking water plant over time
- Occurrence of harmful algal blooms (species, extent, duration, ecological and human health effects)
- Water bodies on Department of Environmental Protections planning or verified lists for impairments
- Tributyltin (TBT) concentration levels (trends in TBT water column concentrations)
- Types and amounts of floatable debris (ocean-side barrier island and estuaries)
- Change in ambient shallow ground-water with respect to established drinking water standards
- Changes in specific conductance
- Amount of contaminant inputs from major point sources and tributaries
- Composition of aquatic debris (floating and in coastal areas)
- Regions of concern: areas with known chemical contaminant-related impacts
- Number of pumpout and dumpstation facilities over time (boat waste)
- Combined sewer overflow (CSO) abatement (frequency of CSO events and volume and duration of overflow events)
- Toxic contaminants in stormwater runoff and receiving waters
- Trends in permitted discharge flow and number of National Pollutant Discharge Elimination System permits
- Sewage disposal and septic tank loads
- Industry reported releases and transfers of chemical contaminants
- Releases and transfers of chemical contaminants from Federal facilities
- Dischargers in significant noncompliance
- Municipal facilities in the watershed using nutrient reduction technology
- Communities implementing stormwater best management practices
- Conversion of septic systems to central sewer
- Removal of direct discharges into the bays
- Concentrations of fecal bacteria (fecal coliform, Enterococci, E. Coli) in surface water as a proportion of criteria/screening levels
- Seagrass acreage change (temperature, pH, total suspended solids, DO, nitrogen, biological oxygen demand (BOD), phosphorus, secchi depth, salinity)
- Non-toxic sewage treatment plants
- Number of volunteer water quality monitoring stations
- Concentration of toxics in sediment and biota (number of water bodies on 303(d) list-in general or for contaminants of concern)
- Safety at swimming beaches: Enterococcus levels and number of beach closures
- Trends in dry weather bacterial indicator concentrations (fecal coliform, e coli, Enterococcus)
- Trends in wet weather bacterial indicator concentrations

INDICATORS DEVELOPED BY VARIOUS GROUPS

- Bacteria load from wastewater treatment plants (fecal coliform, total coliform, flow)
- Macroalgal biomass (measure of benthic productivity)
- Pollution trends
- Acres of cropland under nutrient management
- Eelgrass nutrient pollution index
- Distribution of nuisance macroalgae
- Other toxic substances in groundwater (nitrate)
- Pesticides in ground and surface waters
- Number of petroleum and chemical spill reports over time (total volume spilled)

Contaminants/Sediments

- Sediment chemistry (using U.S. Environmental Protection Agency [EPA] National Coastal Assessment [NCA] data)
- Sediment toxic contamination (metals, PAHs, PCBs, pesticides, dioxins, furans, butyl Tins, and halogenated hydrocarbon)
- Sediment toxicity (toxicity of sediment elutriate to *Ampelisca*)
- Benthic community structure, composition (species and numerical data), and health (total number of benthic species, total number of individuals [abundance], and biomass)
- Benthic index for mud flat, salt flats, and subtidal unvegetated (population density of selected infauna, concentration of contaminants of concern, salinity, grain size, and DO)
- Sediment trends in rivers entering the bay: flow adjusted concentration and monitored loads
- Water quality—contaminated sediment (benthic toxicity and organic toxicity)
- Concentrations of selected contaminants in sediment as a proportion of probable effects level
- Suspended sediments
- Freshwater macroinvertebrate community (wide array of sample statistics including a summary index of biotic integrity)
- Benthos (marine)
- Sediment contaminant concentrations relative to National Oceanic and Atmospheric Administration (NOAA) guidelines
- Trends in sediment contaminant concentrations
- Other toxic substances in biota (chlordane, DDT, metals, PCBs, polychlorinated dibenzodioxins, polychlorinated dibenzofurans, mercury, cadmium)
- Macroinfauna species
- Meiofaunal species
- Organic pollutants in sediment (volatile and semivolatile organic compounds, polychlorinated naphthalenes)
- Sediment composition
- Percent organic carbon in sediment

Land Use

- Land Use/land cover (riparian zones, wetland area, agriculture near water, amount of edges, dominance, miles of roads, amount of agriculture and urban area, contagion, fractal dimension, recovery time, edge amount per patch sized, land cover transition matrix, corridors between patches, diffusion rates, inter-patch distances, actual vs. potential vegetation, percolation thresholds, largest patch, loss of rare land cover, habitat for endangered species)
- Coastal habitat restoration (acreage and diversity of coastal habitats restored to healthy and historic ecological functions, tidal wetlands, freshwater wetlands, estuarine embayments, coastal and inland forest, beaches and dunes, cliffs and bluffs, coastal grasslands, intertidal flats, rocky intertidal zones, submerged aquatic vegetation and shellfish reefs)
- Habitat restoration (number of restoration projects (a) planned; (b) in progress; (c) implementation completed)
- Percent forest cover (acreage of tree cover)
- Habitat opportunity (number of reconnections between open water and diked or levied former tidal habitats)
- Habitat loss (number of dredging, fill and shoreline permits issued)
- Habitat protection and conservation (number of protection and conservation projects (a) planned; (b) in progress; (c) implementation completed) Environmental lands acquisition (acreage of wetlands and environmentally sensitive lands acquired)
- Net change in habitats (sum of number of completed restoration and compensatory mitigation projects minus the sum of all habitat loss projects from dredge, fill, diking, etc.)
- Location of land loss
- Protected open space
- Wetland loss (acres of wetlands lost and index of biological integrity)
- Trends in number, type, or location of wetlands created, enhanced, or preserved
- Land-water ratios by fresh-, brackish-, intermediate-, and saltmarsh habitat type over time
- Specific land-use delineation for developed and agricultural areas
- Change in shoreline habitat/sensitive areas
- Change in stream flow (freshwater inputs)
- Salt marsh extent and condition
- Acreage of land converted to alternate use
- Unfragmented blocks of land (unfragmented blocks of land > 250 acres and >2,000 acres)
- Indicators of freshwater wetland functions
- Population and land use trends
 - average lot size
 - number of households
 - farmland acres
 - public parkland
 - developed land

INDICATORS DEVELOPED BY VARIOUS GROUPS

- Public use and access
 - public access points
 - potable water withdrawals
 - human and industrial water consumption
 - projected future water demands
- Extent of turf grass
- Number of sewer and unsewered homes
- Remediated stormwater sites
- Change in number of bay and tributary public access points/areas (boat launches, parks, fishing piers)
- Change in number and location of marine pumpout facilities
- Change in commercial landings and commercial boat licenses
- Change in recreational landings: number and size
- Change in amount of impervious surface (aerial photography and geographic information system (GIS) mapping)
- Interior to edge ratio
- Hydrologic/bathymetric change
- Municipal waste water permit violations
- Number of 303(d) listed streams
- Number and percentage of shorelines hardened-bulkheading
- Number of types of development permits
- Quality, quantity, and identification of outfalls
- Rate of sprawl-low density, residential development (road miles per capita in the coastal watershed)
- Estimated vehicle nitrogen oxide emissions vs. vehicle miles traveled
- Rate of sprawl-fragmentation (habitat fragmentation per capita in the coastal watershed)
- Population levels or relative abundance of key plant and animal species
- Number of listed, rare or endangered species by year as related to habitat acreage

Aquatic Habitat

- Submerged aquatic vegetation habitat (abundance, change, health, distribution, and density by species)
- Area of brown marsh
- Acres of marsh damage by non-native nutria in over time
- Change in base flow of tributary streams over time
- Saltwater intrusion
- Water levels
- Percent exotics within saltwater marshes and location
- Acreage of subbasins that no longer contribute flows to their historic receiving water bodies
- Acreage of subbasins returned to historic receiving water bodies
- Net difference between the acreage of subbasins that no longer contribute flows to their historic receiving water bodies and the acreage of subbasins returned to historic receiving water bodies

- Tidal wetlands, tidal wetlands buffer habitats (wetland acres restored/preserved, number of successful wetland mitigation sites, acreage of wetlands buffered, wetland acres, riparian buffer [miles])
- Overall restoration initiatives (number of acres preserved, restored, enhanced, habitat acres on corporate properties)
- Fish passage/blockages (stream miles opened, stream blockages removed)
- Sneaker index (water clarity and turbidity)
- Percent change in inflows from major tributaries
- Annual gaged freshwater inflows compared to inflow recommendations
- Riparian integrity (percent of riparian zone (50-meter and 100-meter buffer) with native vegetation)
- Distribution of coarse and soft bottoms
- Diversity and composition of Riparian insect assemblages
- Deposition in the estuary (sediment deposition and accumulation, changes in bay bathymetry and tidal prism)
- Erosion in the watershed (changes in channel cross sections due to aggradation and deposition of sediment)
- Portion of channels where newly deposited sediments pass suitability criteria (contaminants in sediments)
- Percentage of navigation projects that contain one or more of the following: environmental dredging for the purpose of toxics reduction, brownfields remediation, habitat acquisition, habitat restoration, improvement of appropriate public access, or beneficial reuse of dredged material
- Other toxic substances in sediments (PCBs, DDT, PAHs, arsenic, copper, lead, mercury, silver, radionuclides)
- Habitat quality
- Biological resources

Other

- Coastal, nesting, threatened, and endangered bird trends, abundance and diversity (population estimates of birds by species)
- Trends abundance, and diversity in waterfowl
- Change in number of waterfowl hunting licenses
- Population condition of endangered species (population size and/or reproductive success [breeding/fledgling pairs, etc.])
- Cost of invasive species control
- Species diversity (wildlife)
- Rare plant and animal populations
- Native species assessment (number of estuarine-linked species listed under Federal or state Endangered Species Act programs)
- Percent non-native species
- Number, frequency, and occurrence of non-native species
- Acreage of non-native sub-macrophytes
- Overall restoration initiatives (habitat acres impaired by invasive species, habitat acres controlled for invasive species)

INDICATORS DEVELOPED BY VARIOUS GROUPS

- Invasive species (species composition and abundance)
- Seals (number of seals)
- Seal tissue toxics (PCBs, dioxins, furans, pesticides, and heavy metals)
- Boating use
- Water allocation
- Soil types
- Alligator nests
- Black bear abundance
- Reptile and amphibian population abundance
- Atmospheric and other pollution inputs (organic pesticides, PCBs, trace metals and byproducts of combustion)
- Population within 50 miles of the watershed (measure population growth and demographic trends to determine potential human use of the resources)
- Trends in shipping traffic versus vessel fuel spills and vessel incidents
- Value of shipping cargo, recreational boating, energy production wells, nature tourism
- Muck removal (volume and acreage of muck deposits removed)
- All dredged material being used beneficially
- Watershed population levels (measure population growth and demographic trends in the Long Island Sound watershed)
- Comprehensive Conservation Management Plan (CCMP) progress
- Best management practices activity
- Population of watershed municipalities
- Percent of communities implementing development that works
- Percent of communities implementing policies of public participation
- Beach clean-up volunteers (number of volunteers)
- Debris collected during International Coastal Cleanup (composition of debris, weight of debris, miles of shoreline cleaned)
- Website visitors (number of times the web site is accessed by the public per year)
- Number of environmental organizations (dates/times, participation numbers, and number of events)
- Number of environmental activities-specific (dates/times, participation numbers, and number of events)
- Number of environmental science courses/sections
- Number of kids reached in classrooms, field projects, on-river, service learning
- Number of school districts
- Number of teachers in estuary-related training courses
- Number of adults completing environmental science training
- Number of teachers working with estuary partnership or estuary partnership curriculum
- Number of non-formal K-12 environmental projects, events
- Number of partnerships between schools and outside entities
- Number of class visits to learning centers for an organized experience related to the estuary

- Number of educational materials distributed over time
- Number of volunteers involved: restoration projects, clean up projects, and water quality monitoring (number of projects, number of volunteers, number of first time volunteers, number of returning volunteers, and is the demand growing)
- Number of media hits
- Number of recycling programs
- Number of license plates sold
- Cumulative number of businesses recognized as stewards of the estuary
- Number and value of flood insurance claims over time
- Revenues and jobs generated by tourism over time

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APPENDIX C

RESOURCES ON INDICATORS

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